Narrow Bandwidth High Power IR OPOs with Volume Bragg Gratings

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Optical parametric oscillators (OPO) using quasi phase-matched (QPM) crystals can be more efficient than with birefringent phase-matching. Reasons for this include access to higher effective nonlinearity and lack of walk-off. A major disadvantage in some applications is the broad gain bandwidth close to degeneracy. This is especially a concern when the generated signal is used for further nonlinear interactions, for example as a pump source for a second OPO. Tandem OPO systems where one OPO pumps a second OPO are one of few working methods to generate high power at wavelengths longer than 4 μm. The reason for this is that the nonlinear crystals that are transparent at long wavelengths (most notable ZGP and orientation patterned GaAs) need to be pumped at wavelengths close to or longer than 2 μm.

One solution to the broad bandwidth in near degenerate QPM OPOs that shows promising results is to use a volume Bragg grating (VBG) as a cavity mirror in the OPO. The grating gives feedback only in a narrow spectral region limiting oscillation to the longitudinal modes that are within this region. Measurements have shown that with a multi-longitudinal mode pump laser oscillation can be limited to almost a single longitudinal mode in the signal. The idler then of course takes on the spectral width of the pump. With a 0.5 nm design bandwidth of the Bragg grating a total spectral width of signal and idler of less than 2 nm was measured in a singly resonant cavity, limited by measurement resolution.

As the extra loss from the VBG is very low, on the order of 1-2 % from scattering and residual surface reflection, the conversion efficiency is not significantly reduced compared to a standard OPO with dichroic cavity mirrors. Using a PPKTP crystal with uncoated surfaces a slope efficiency of 34 % was measured in a cavity with a dichroic mirror input coupler and a volume Bragg grating output coupler.

Using a PPKTP OPO with a VBG output coupler with signal and idler separated by 9 nm a slope efficiency of 54 % was reached in a ZGP OPO with a single 14 mm long crystal and flat cavity mirrors. In total 1.95 W average power was generated in the 3.5-5 μm wavelength region at 10 kHz repetition rate with 21 W pump at 1.064 μm before the incoupling mirror to the first OPO. With a pump wavelength centered at 2128 nm the ZGP OPO can be tuned so that the signal and idler fits the 3.5-4.2 μm and 4.6-5.5 μm atmospheric transmission windows, respectively. The tandem OPO setup is thus very suitable for stand off applications as directed infrared countermeasures (DIRCM) and lidar.